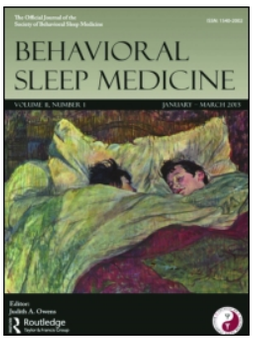

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When Thinking Impairs Sleep: Trait, Daytime and Nighttime Repetitive Thinking in Insomnia

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We performed two studies in individuals with sleep problems to investigate trait, daytime, and nighttime repetitive thinking as risk factors for insomnia. In Study 1, 139 participants completed questionnaires on worry, rumination, insomnia, anxiety, depression, and a sleep diary. Trait rumination and trait worry were not associated with sleep impairment. In Study 2, 64 participants completed similar measures and a daytime and nighttime sleep-related worry diary. Only nighttime sleep-related worry was consistently associated with sleep impairment. Overall, results indicate that nighttime sleep-related worry is important in the maintenance of insomnia, whereas effects of trait and daytime repetitive thinking are more benign. Treatment for insomnia can potentially be improved by focusing more on nighttime sleep-related worry.

Insomnia has a prevalence of about 10% (Ohayon, 2002) and is associated with high societal costs (Daley, Morin, LeBlanc, Gregoire, & Savard, 2009). According to the *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; DSM-5), insomnia is a condition characterized as suffering from difficulties initiating or staying asleep. These sleep complaints need to be present for at least three months, cannot be explained by another disorder, and have negative daytime consequences (American Psychiatric Association, 2013). Indeed, people with insomnia

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experience concentration problems (Kamdar, Kaplan, Kezirian, & Dement, 2004), heightened irritability and emotional instability (Strine & Chapman, 2005), and an increased likelihood of being involved in accidents (Leger, 1995). In the long term, disturbed sleep is associated with a variety of physical and mental health problems, including anxiety and depression (e.g., Irwin et al., 1996; Taylor, Lichstein, Durrence, Reidel, & Bush, 2005).

Cognitive behavioral therapy for insomnia (CBT-I) is currently the most effective treatment for insomnia (Irwin, Cole, & Nicassio, 2006; Morin et al., 2006; Morin et al., 1999; Rieman & Perlis, 2009; Smith et al., 2002). However, even with the best available CBT-I treatment, a significant number of insomnia patients do not improve, or only partly improve (Morin & Benca, 2012). Increasing the effectiveness of CBT-I is therefore of outstanding importance. In particular, identification of modifiable risk factors that contribute to the development and maintenance of insomnia is essential, so that these can be targeted during psychological treatment.

One potential modifiable risk factor for insomnia is repetitive thinking (Borkovec, 1982; Perlis, Giles, Mendelson, Bootzin, & Wyatt, 1997; Morin, 1993). Repetitive thinking, originally studied in the context of anxiety and depression (for reviews, see Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008; Watkins, 2008), is defined as "the process of thinking attentively, repetitively, or frequently about oneself and one's world" (Segerstrom, Stanton, Alden, & Shortridge, 2003, p. 909). In an influential cognitive model of insomnia, Harvey (2002) proposed that excessive daytime and nighttime repetitive thinking about possible sleep deficits and the impact of sleep disturbance leads to arousal and distress, which in turn leads to selective attention and increased monitoring of sleep-related threats. This selective attention results in overestimation of sleep impairment and daytime consequences, which maintains repetitive thinking about sleep and increases physiological arousal, causing real impairment in sleep and daytime functioning.

Specifically, two types of repetitive thinking have been proposed to play an important role in insomnia: worry and rumination (Carney, Harris, Moss, & Edinger, 2010). Worry is a coping strategy that consists of engaging in abstract repetitive verbal thinking focused on uncertain events with a potential future negative outcome (Borkovec, Ray, & Stöber, 1998; Borkovec, Robinson, Pruzinsky, & Depree, 1983). Rumination, on the other hand, is a coping strategy that consists of abstract repetitive thinking on the causes and consequences of negative emotions (Nolen-Hoeksema et al., 2008).

The relationship between repetitive thinking and sleep problems has been supported by various studies over the past decades (Akerstedt, Kecklund, & Axelsson, 2007; Harvey, 2000; Kales et al., 1984; Takano, Iijima, & Tanno, 2012; Thomsen, Mehlsen, Christensen, & Zachariae, 2003; Watts, Coyle, & East, 1994; Zoccola, Dickerson, & Lam, 2009). However, researchers have frequently relied on student samples (Takano et al., 2012; Thomsen et al., 2003; Zoccola et al., 2009), used general insomnia questionnaires rather than diaries to assess sleep (Takano et al., 2012; Thomsen et al., 2003; Watts et al., 1994), or focused exclusively on the effects of either worry *or* rumination instead of comparing the effects of multiple types of repetitive thinking on sleep disturbance (Akerstedt et al., 2007; Harvey, 2000; Kales et al., 1984; Thomsen et al., 2003; Watts et al., 1994; Zoccola et al., 2007).

Recently, some advancements have been made in research on repetitive thinking and sleep. In particular, Carney and colleagues (2010) compared the effects of worry and rumination during the past week on sleep timing measures assessed with a sleep diary in a large sample of adults with clinical insomnia. Their results provided no substantial support for a relationship between repetitive thinking and sleep problems, with no association between worry and sleep disturbance, and only a small association between rumination and sleep disturbance. Notably, in a similar

study, O'Kearney and Pech (2014) also failed to find an association between trait worry and sleep impairment in insomnia.

Given the central role of repetitive thinking in cognitive theories on insomnia, these results are in need of an explanation. One potential reason for this pattern of results is that a general tendency to engage in repetitive thinking is not the central factor that determines sleep disturbance. Instead, the specific time of day during which an individual engages in repetitive thinking may be crucial. As mentioned, the cognitive model by Harvey (2002) predicts that both daytime and nighttime repetitive thinking fuel arousal and attention and perception biases that underlie sleep problems in insomnia. Yet, there is a lack of research investigating the role of timing of repetitive thinking on sleep disturbance. In fact, only a few studies have explored this topic, and those that did provided some evidence that nighttime repetitive thinking is especially important in sleep. For example, Wicklow and Espie (2000) found that intrusive thinking assessed with nighttime recordings was a strong predictor of sleep onset latency. More recently, worry in bed, but not trait worry, was linked with both subjective and objective measures of sleep disturbance (Weise, Ong, Tesler, Kim, & Roth, 2013).

A second plausible explanation for the modest association between general repetitive thinking and impaired sleep is that sleep-related repetitive thinking (as opposed to a general tendency to engage in repetitive thinking) is more important in the maintenance of insomnia. In fact, Harvey (2002) specifically predicted relationships between sleep-related cognitive activity and sleep problems. In line with this theory, O'Kearney and Pech (2014) found that sleep-specific worry, but not trait worry, was associated with higher sleep onset latency and lower sleep efficiency. However, in their study, sleep-related worry was measured only once instead of on a day-to-day basis. The use of sleep-related worry diary data could provide a stronger test for the assumption that sleep-related repetitive thinking instead of general repetitive thinking perpetuates sleep disturbance in insomnia.

In the current investigation, we aimed to investigate the role of general repetitive thinking, timing of repetitive thinking, and the role of sleep-related worry in sleep disturbance in two samples with elevated levels of insomnia. We performed two studies: In study 1, we aimed to replicate the work of Carney and colleagues (2010) by investigating whether the trait tendency to ruminate and worry predicts sleep impairment, even when controlling for anxious and depressive symptoms. Although Carney and colleagues only found support for a relationship between rumination and sleep disturbance, other research did support a relationship between worry and sleep disturbance (Akerstedt, et al., 2007; Harvey, 2000; Kales et al., 1984; Takano et al., 2012; Watts et al., 1994). Therefore, we predicted that both rumination and worry would show a relationship with sleep continuity measures. However, in line with Carney and colleagues (2010), we additionally predicted that rumination would show stronger effects on sleep than worry.

In study 2, we were not as much interested in the differentiation between trait rumination and trait worry in insomnia. Based on findings from the literature (O'Kearney & Pech; Weise et al., 2013; Wicklow & Espie, 2000), we now set out to investigate the role of daytime and nighttime sleep-related repetitive thinking in relation to sleep problems in a sample of people with elevated levels of insomnia. When designing this study, no validated measure of sleep-related rumination was yet available (but see Carney, Harris, Falco, & Edinger, 2013). A sleep-related worry questionnaire had been published (Tang & Harvey, 2004), and therefore, we chose to assess daytime and nighttime sleep-related worry. We predicted that daytime and nighttime sleep-

related worry would both be related to sleep disturbance even after controlling for trait repetitive thinking, anxiety, and depression. Based on prior findings (Weise et al., 2013; Wicklow & Espie, 2000), we further hypothesized that nighttime sleep-related worry would be a stronger predictor of sleep problems than daytime sleep-related worry.

METHODS: STUDY 1

Participants

Participants were recruited from January 2012 to April 2013 on a Dutch popular-science website about insomnia (www.insomnie.nl). On this website, people interested in participation in sleep research could fill out the insomnia scale of the SLEEP-50 questionnaire (Spoormaker, Verbeek, van den Bout, & Klip, 2005). If they screened positive for insomnia, they could leave their e-mail address to participate in future insomnia studies. In April 2013, all people that had screened positive (n = 1,551) were e-mailed with information for study 1. Of these 1,551 individuals, 237 completed an informed consent form and started an online questionnaire.

Of the 237 persons that started the online questionnaire, 38 could not be included for the following reasons: insufficient insomnia complaints based on the Insomnia Severity Index (n = 1; cutoff < 8; Bastien, Vallières, & Morin, 2001), not 30 min a night awake for at least three nights a week (n = 7), possible sleep apnea (n = 18; cutoff > 15; Spoormaker et al. 2005), alcohol abuse (n = 8; more than three glasses of alcohol a day for at least 21 days a month), marijuana abuse (n = 3; use more than once a week), schizophrenia or psychosis (n = 0), and current suicidal plans (n = 0; thus people with only suicidal ideation were not excluded). Another 22 did not finish the questionnaire, 20 did not start the sleep diary and 18 people completed their diary on less than 7 (out of 10) days.

This resulted in a final sample of 139 participants. The mean age of these participants was 48.3 (SD = 14.2, range 21–78). Sixteen participants (11.5%) were receiving psychological treatment, 23 (16.5%) reported that their sleeping problems were due to a physical condition, 51 (36.7%) reported sleep medication use, and 16 (11.5%) used medication other than for sleeping. Summary statistics for the questionnaires and diaries are displayed in Supplemental Table 1.

Materials

Diary

For 10 days, participants filled out an online sleep diary in the morning (the e-mail was sent at 6:00 a.m.). They recorded time to bed, final arising time, sleep onset latency (SOL), wake after sleep onset (WASO), number of nocturnal awakenings (NWAK), sleep quality (SQ; 1 = "very bad" to 5 = "very good"), and use of sleep medication. From these variables, the time in bed (TIB = final arising time − time to bed), total sleep time (TST = TIB − SOL − WASO), and sleep efficiency (SE = [TST/TIB] × 100) were calculated. These variables were averaged over the 10-day period.

Questionnaires

Depressive symptoms were measured using a Dutch translation of the 20-item Centre of Epidemiological Studies–Depression Scale (CES-D; Bouma, Ranchor, Sanderman, & van Sonderen, 1995; Radloff, 1977). The CES-D ranges from 0 (no indication for depression) to 60 (high indication for depression). This scale has good internal consistency (α = 0.79–0.92; in the current studies, α =.79; .89).

Anxiety symptoms were measured with the Dutch version of the seven anxiety items of the Hospital Anxiety and Depression Scale (HADS; Spinhoven et al., 1997; Zigmond & Snaith, 1983). The HADS ranges from 0 (no anxiety symptoms) to 21 (severe symptoms of anxiety). The reliability of the HADS is good (α = 0.80–0.84, in the current studies α = .85; .82).

Insomnia complaints were measured with a Dutch translation of the seven-item Insomnia Severity Index. The English questionnaire is a valid and reliable measure to detect changes in insomnia severity (internal consistency α = 0.78; Bastien et al., 2001; Morin, 1993; α in the current studies =.62; .60). The score ranges from 0 (no insomnia) to 28 (severe insomnia). A cutoff of 7 is used to determine subclinical insomnia.

The SLEEP-50 (Spoormaker et al., 2005) was used to screen whether volunteers had insomnia complaints (α = .85). This scale has eight items and the score ranges from 8 (no insomnia symptoms) to 32 (severe insomnia symptoms). This subscale has a sensitivity of .71 and a specificity of .75 compared to clinical diagnosis. The SLEEP-50 was also used to screen for apnea (eight items; α = 0.51; sensitivity of .85 and a specificity of .88). The score ranges from 8 (no apnea symptoms) to 32 (severe apnea symptoms).

Trait worry was measured with the 16-item Penn State Worry Questionnaire (PSWQ; Meyer, Miller, Metzger, & Borkovec, 1990). The score ranges from 16 (low tendency to worry) to 80 (high tendency to worry). The Dutch version of the PSWQ (van Rijsoort, Emmelkamp, & Vervaeke, 1999) was shown to have a high internal consistency: α = .94 (α in this study was .88).

Trait rumination was measured with the 26-item Ruminative Response Scale (RRS; Nolen-Hoeksema & Morrow, 1991). In this study, the Dutch translation of the RRS was used (Raes & Hermans, 2007), for which adequate reliability was reported (Schoofs, Hermans, & Raes, 2010). Cronbach's α was .94 in this study. The score ranges from 26 (low tendency to ruminate) to 104 (high tendency to ruminate). Since only the eight-item Symptom Focused Rumination (SFR) subscale (Bagby & Parker, 2001) can adequately distinguish between poor and good sleepers (Carney, Edinger, Meyer, Lindman, & Istre, 2006), we used this subscale (range 8 to 32) in our analyses (α in this study was .85).

Procedure

The study was designed in line with the Declaration of Helsinki and approved by the internal Ethical Review Board of the University of Amsterdam. People who met study criteria filled out questionnaires first (CES-D, HADS-A, ISI, PSWQ, RRS). After filling out these questionnaires, they received a digital sleep diary for a period of 10 days (the diary was sent by e-mail each morning at 6:00 a.m.). Participants were required to fill out their diary before a subsequent diary was sent. After completing the study, participants received an online intervention for insomnia, free of charge (Lancee, van den Bout, Sorbi, & van Straten, 2013).

Statistical Analyses

We performed forced-entry hierarchical regression analyses for the mean scores of the dependent variables *sleep efficiency, total sleep time, sleep onset latency, wake after sleep onset*, and *sleep quality*. The independent variables were depression (CES-D), anxiety (HADS-A), age (because of its known association with sleep; Ohayon, 2002; Ohayon, Carskadon, Guilleminault, & Vitiello, 2004), symptom rumination (RRS), and worry (PSWQ). We used two blocks; in the first block, we included anxiety, depression, and age. In the second block, we added trait rumination and worry. Assumptions were checked for the residuals and we detected one multivariate outlier on wake after sleep onset. We ran the analyses with and without this case included in our data set and this did not change the results of our analyses. Therefore, we decided to retain these cases in the analyses.[1]

RESULTS: STUDY 1

Correlations

Baseline worry was only significantly associated with total sleep time, $r = .23$, $p = .006$, and sleep efficiency, $r = .23$, $p < .007$. Symptom-focused rumination was associated with wake after sleep onset, $r = -.17$, $p = .04$. For all the first-order correlations, see Supplemental Table 2.

Multiple Regression

The full model significantly predicted (a) sleep efficiency, $F(5,133) = 7.67$, $p < .001$, $R^2_{adj} = 19.5\%$, (b) total sleep time, $F(5,133) = 8.11$, $p < .001$, $R^2_{adj} = 20.5\%$, and (c) wake after sleep onset, $F(5,133) = 4.76$, $p < .001$, $R^2_{adj} = 12.0\%$. In these models, the only significant predictor was age (Table 1). In the model predicting sleep quality, $F(5,133) = 3.92$, $p = .002$, $R^2_{adj} = 9.6\%$, age and depression were both significant predictors. No significant effects were found for sleep onset latency, $F(5,133) = 1.51$, $p = .19$, $R^2_{adj} = 1.8\%$. Both worry and rumination showed no significant relationships with any of the sleep measures (all p's $> .05$).

METHODS: STUDY 2

Participants

Participants were recruited in a similar manner as in study 1, but now from April 2013 to January 2014. In October 2013 and January 2014, all people who had screened positive ($n = 1{,}500$) were

[1] In study 1 we also aimed to include a daytime and nighttime repetitive thinking diary. We decided not to report on this data. We made this decision because the data seemed contaminated; participants generally scored very low on the repetitive thinking diary that included the Penn State Worry Questionnaire–Past Day (PSWQ-PD; Joos et al., 2012) and the Ruminative Response Scale–Past Day (RRS-10-PD). For example, the mean score of the PSWQ-PD in study 1 was 15.70 ($SD = 11.97$), while a student sample had a mean score of 22.45 ($SD = 12.73$; Joos et al., 2012). Conversely, the trait worry scores in our sample on average fell in the norm group of high scorers (norm group – high = 49–59; Van der Heiden, Muris, Bos, van der Molen, & Oostra, 2009). Notably, the pattern we observed in the diary data of study 1 was similar to the pattern we found in study 2: Daytime repetitive thinking was unrelated to sleep problems, whereas nighttime repetitive thinking was positively related to sleep problems.

TABLE 1
Study 1: Regression coefficients for sleep efficiency, total sleep time, sleep onset latency, wake after sleep onset, and sleep quality.

	SE		*TST*		*SOL*		*WASO*		*SQ*	
	B (SE)	*β*	B (SE)	*β*	B (SE)	*β*	B (SE)	*β*	B (SE)	*β*
Step 1										
Anxiety (HADS)	0.42(0.36)	0.13	2.00 (2.21)	.10	–1.03 (1.16)	–.11	–1.03 (1.74)	–.07	0.03 (0.02)	.18
Depression (CESD)	–0.11(0.14)	–.09	–0.75 (0.85)	–.10	0.53 (0.44)	.15	–0.09 (0.66)	–.02	–0.02 (0.01)	–28*
Age	–0.39(0.07)	–.46***	–2.49 (0.41)	–.47***	0.38 (0.21)	.15	1.41 (0.32)	.36***	–0.01 (0.003)	–.30**
R^2_{adj}	20.4%		21.0%		1.0%		12.9%		8.8%	
Step 2										
Anxiety (HADS)	0.33 (0.40)	.10	0.94 (2.43)	.05	–0.42 (1.27)	–.05	–1.47 (1.91)	–.10	0.01 (0.02)	.18
Depression (CESD)	–0.12 (0.15)	–.10	–1.00 (0.93)	–.13	0.48 (0.49)	.14	–0.08 (0.66)	–.02	–0.02 (0.01)	–.37**
Age	–0.38 (0.07)	–.45***	–2.35 (0.43)	–.45***	0.32 (0.23)	.13	1.46 (0.34)	.37***	–0.01 (0.004)	–.24**
Rumination (RRS)	–0.02 (0.10)	–.02	0.02 (0.64)	.00	0.40 (0.33)	.15	–0.23 (0.50)	–.06	0.01 (0.01)	.14
Worry (PSWQ)	0.06 (0.11)	.07	0.65 (0.65)	.12	–0.59 (0.34)	–.23φ	0.39 (0.52)	.10	0.01 (0.01)	.12
ΔR^2_{adj}	–0.9%		–0.5%		1.0%		–0.9%		0.8%	

Note. φ: $p < .1$; * = $p < .05$; SE = Sleep efficiency; SOL = Sleep onset latency; SQ = sleep quality (1-5); TST = Total sleep time; WASO = Wake after sleep onset.

e-mailed with information for study 2. In addition, people were recruited via a Facebook ad campaign. In the end, 109 individuals interested in the study completed an informed consent form and started the online questionnaire. Of these volunteers, five had insufficient insomnia complaints based on the Insomnia Severity Index (cutoff < 8; Bastien et al., 2001) or did not lie awake for at least 30 min a night at least three nights a week. People were also excluded for possible sleep apnea (n = 3; cutoff > 15; Spoormaker et al., 2005), shift-work (n = 5), earlier CBT for insomnia (n = 7), starting psychotherapy in the last six months (n = 7), alcohol abuse (n = 2; more than three glasses of alcohol a day for at least 21 days a month), marijuana abuse (n = 3; use more than once a week), schizophrenia or psychosis (n = 0), and current suicidal plans (n = 0). Of the remaining 77 people, another 13 did not complete the questionnaire or filled out their diary on less than six (out of seven) days.

This resulted in a final sample of 64 participants with a mean age of 48.1 (SD = 14.2, range 22–83; age was based on n = 56), and 51 (79.7%) women. Of the participants, one (1.6%) received psychological treatment, seven (10.9%) reported that their sleeping problems were due to a physical condition, 20 (31.3%) reported prescribed sleep medication use in their diary, and three (4.7%) used medication other than for sleeping. Summary statistics for the diaries and questionnaires are displayed in Supplemental Table 3.

Materials

Diary

Participants kept a sleep diary for seven days. We used an improved version of the sleep diary of study 1. Now we used a Dutch translation of the consensus sleep diary (Carney et al., 2012). This meant that time in bed was specified to "time you tried to go to sleep." We now also measured "terminal wakefulness" (amount of time between awakening and getting out of bed). In this study, sleep diary scores were not averaged but data from each separate day was used in the analyses.

Participants additionally filled out an adapted version of the Anxiety and Preoccupation about Sleep Questionnaire (APSQ; Tang & Harvey, 2004; α = 0.92) every morning to assess nighttime sleep-related worry (e-mail 6:00 a.m.; α = .95 in this sample) and every evening to assess daytime sleep-related worry (e-mail 7:00 p.m.; α = 0.93 in this sample). The APSQ is a 10-item questionnaire that was developed to measure sleep-related worry about the amount and consequences of sleep deficiencies. In accordance with Jansson-Fröjmark, Harvey, Lundh, Norell-Clarke, & Linton (2010) we used a 1–5 Likert scale, so scores range from 10 (low indication sleep-related worry) to 50 (high indication sleep-related worry). In a recent study, it was found that the APSQ is a valid instrument to assess worry typical of people with insomnia (Jansson-Fröjmark et al., 2010). We translated this questionnaire and adapted it to diary use by preceding the questions with "the past day/past night" (e.g., "I worried about the amount of sleep I am going to get").

In the evening, daytime stress was measured with a subscale of the Dutch version of the Depression Anxiety Stress Scale 21 (DASS-21; de Beurs, Van Dyck, Marquenie, Lange, & Blonk, 2001; Lovibond & Lovibond, 1995). The stress scale of the DASS consists of seven items. The items are scored on a 0–3 Likert scale and the sum score is multiplied by two in order be comparable with the longer DASS scale. Score ranges thus from 0 (low stress) to 42 (high

stress). The Dutch version proved to be reliable with α =.89 (α = .89 in this sample). We adapted this scale to measure daily stress. We changed the instruction preceding the questionnaire from "'applied to you over the past week" into "applied to you in the past day."

Questionnaires

In study 2, the CES-D (Radloff, 1977), the HADS (Zigmond & Snaith, 1983), and the ISI (Morin, 1993) were administered. Please see the methods section for study 1 for a description and their psychometric properties.

Furthermore, the general tendency to engage in repetitive thinking independent of disorder-specific content (for which the PSWQ and RRS have been criticized) was measured using the 15-item Perseverative Thinking Questionnaire (PTQ; Ehring, Zetsche, Weidacker, Wahl, Schönfeld, & Ehlers, 2011). Items are rated on a scale from 0 (never) to 4 (almost always); the score ranges from 0 (no indication for repetitive thinking) to 60 (high indication for repetitive thinking). The psychometric properties of the PTQ are good (Ehring, Raes, Weidacker, & Emmelkamp, 2012; α in the current study = .97).

Procedure

The study was in line with the Declaration of Helsinki and approved by the internal Ethical Review Board of the University of Amsterdam. People were participants in a randomized controlled trial (Lancee, Eisma, van Straten, & Kamphuis, 2015) on the role of cognitions in cognitive behavioral treatment for insomnia. Participants who met the study criteria then filled out questionnaires (ISI, CES-D, HADS-A, PTQ). Thereafter they received two digital diaries a day for a period of seven days. A sleep or sleep-related worry diary was sent by e-mail each morning at 6:00 a.m. and a sleep-related worry and stress diary was sent by e-mail each evening at 7:00 p.m.. Participants were required to fill out their diary before a subsequent diary was sent. After completing all diaries, participants were randomized into online CBT-I or a waiting-list condition.

Statistical Analysis

We used multilevel regression analyses to evaluate the relationship between the independent and dependent variables (Hox, 2002). This method was used because it can take the nested structure of data into account. In this study, the data had a two-level structure with time points (days) nested within individuals. A major advantage of multilevel regression is that it can handle missing data very well. As a consequence, people who did not fill out diaries on all days or did not fill out a diary on time could still be included in the analyses. This meant that we were able to analyze the data on a day-to-day level without losing too much data (i.e., if a day was missing, only data from that day was dropped from the analysis but the other data points of the participant could be retained in the model).

Diaries that were not filled out on time (same day) were excluded from our analyses. In the final data set, we had 396 of the 448 diary entries reliably at our disposal (88.4%). In all analyses, a random intercept was included. Again, we controlled for depression and anxiety. We also included "day" (e.g., Monday, Tuesday, etc.) to control for possible time influences (e.g., weekdays vs. weekend days). Explained variance was calculated based on the reduction of the

variance components (Snijder & Bosker, 2012). A significance level of $p < .05$ (two-sided) was used throughout the study.

RESULTS: STUDY 2

Correlations

Daytime sleep-related worry (APSQ-day) was significantly related to total sleep time, $r = -.11$; $p = .04$, wake after sleep onset, $r = .15$; $p = .004$, and sleep quality, $r = -.15$; $p = .006$. Nighttime sleep-related worry (APSQ-night) was significantly related to sleep efficiency, $r = -.25$; $p < .001$, total sleep time, $r = -.28$; $p < .001$, sleep onset latency, $r = .22$; $p < .001$, wake after sleep onset, $r = .22$; $p < .001$, and sleep quality, $r = -.35$; $p < .001$. For the remaining first-order correlations please see Supplemental Table 4.

Multilevel Regression Analyses

In the multilevel regression models, the independent variables predicted 3.6–17.1% of the variance of the dependent variables (Table 2). We found that nighttime sleep-related worry was significantly associated with sleep efficiency, $b = –1.19$; $SE = 0.16$, $p < .001$, total sleep time, $b = –6.67$; $SE = 0.88$, $p < .001$, sleep onset latency, $b = 2.35$; $SE = 0.31$, $p < .001$, wake after sleep onset, $b = 2.16$; $SE = 0.48$, $p < .001$, terminal wakefulness, $b = 0.91$; $SE = 0.41$, $p = .03$, and sleep quality, $b = –0.06$; $SE = 0.01$, $p < .001$. Daytime sleep-related worry was significantly associated with sleep quality, $b = 0.02$; $SE = 0.01$, $p = .002$, but not with sleep efficiency, $b = 0.33$; $SE = 0.18$, $p = .08$, total sleep time, $b = 1.39$; $SE = 0.99$, $p = .16$, sleep onset latency, $b = –0.63$; $SE = 0.35$, $p = .07$, wake after sleep onset, $b = –0.28$; $SE = 0.53$, $p = .60$, and terminal wakefulness, $b = –0.12$; $SE = 0.09$, $p = .17$. Notably, all the relationships between daytime worry and sleep indices were now in the opposite direction of the zero-order correlations.

Trait repetitive thought (PTQ) was significantly associated with sleep quality, $b = 0.01$; $SE = 0.005$, $p = .05$. Anxiety and depression were not significantly associated with any of the dependent variables (all p's > .1).

DISCUSSION

In the current report, we described two studies investigating if general repetitive thinking and daytime and nighttime sleep-related worry are risk factors in the maintenance of insomnia.

In study 1, we investigated the role of trait rumination and trait worry in sleep disturbance. We found no relationship between trait rumination and trait worry and sleep impairment when controlling for age, depression, and anxiety. The finding that trait worry and rumination were unrelated to sleep continuity measures is in direct contrast with previous research (e.g., Harvey, 2000; Takano et al., 2012; Thomsen et al., 2003; Zoccola et al., 2009). However, as mentioned before, earlier studies were often done in student samples or used general sleep questionnaires. Similar research as ours also found no or small associations between worry or rumination and sleep disturbance (Carney et al., 2010; O'Kearney & Pech, 2014). Together, these recent studies (Carney et al., 2010;

TABLE 2
Study 2: Multilevel regression analyses for sleep efficiency, total sleep time, sleep onset latency, wake after sleep onset, terminal wakefulness, and sleep quality.

	b	(SE)	β	(SE)
		Sleep efficiency - SE		
Constant	72.7	(6.65)***		
Day	0.67	(0.46)	0.06	(0.04)
Baseline				
Anxiety (HADS-A)	0.07	(0.74)	0.01	(0.11)
Depression (CES-D)	0.20	(0.30)	0.08	(0.12)
Repetitive thought (PTQ)	0.26	(0.16)	0.16	(0.10)
Diary				
Nighttime worry (APSQ)	-1.19	(0.16)***	-0.53	(0.08)***
Daytime worry (APSQ)	0.33	(0.18)φ	0.14	(0.08)φ
Stress (DASS)	0.12	(0.33)	0.02	(0.07)
R^2		13.9%		
		Total sleep time - TST		
Constant	361.8	(35.91)***		
Day	7.52	(2.49)**	0.12	(0.04)**
Baseline				
Anxiety (HADS-A)	0.23	(4.03)	0.01	(0.10)
Depression (CES-D)	0.77	(1.64)	0.06	(0.12)
Repetitive thought (PTQ)	1.67	(0.88)	0.18	(0.09)
Diary				
Nighttime worry (APSQ)	-6.67	(0.88)***	-0.54	(0.07)***
Daytime worry (APSQ)	1.39	(0.99)	0.11	(0.08)
Stress (DASS)	0.72	(1.77)	0.03	(0.06)
R^2		17.1%		
		Sleep onset latency - SOL		
Constant	10.41	(14.96)		
Day	-1.25	(0.83)	-0.05	(0.03)
Baseline				
Anxiety (HADS-A)	1.11	(1.78)	0.08	(0.12)
Depression (CES-D)	-0.82	(0.72)	-0.16	(0.14)
Repetitive thought (PTQ)	0.29	(0.39)	0.08	(0.11)
Diary				
Nighttime worry (APSQ)	2.35	(0.31)***	0.51	(0.07)***

(*Continued*)

TABLE 2
(Continued)

	b	(SE)	β	(SE)
Daytime worry (APSQ)	-0.63	(0.35)φ	-0.13	(0.07)φ
Stress (DASS)	-0.63	(0.61)	-0.06	(0.06)
R^2		12.5%		
		Wake after sleep onset - WASO		
Constant	58.34	(17.52)		
Day	-1.84	(1.40)	-0.06	(0.04)
Baseline				
Anxiety (HADS-A)	-0.40	(1.88)	-0.02	(0.10)
Depression (CES-D)	-0.45	(0.77)	-0.07	(0.11)
Repetitive thought (PTQ)	-0.76	(0.41)	-0.17	(0.09)
Diary				
Nighttime worry (APSQ)	2.16	(0.48)***	0.36	(0.08)***
Daytime worry (APSQ)	-0.28	(0.53)	-0.04	(0.08)
Stress (DASS)	-0.26	(0.96)	-0.02	(0.07)
R^2		7.6%		
		Terminal wakefulness - TWAK		
Constant	60.64	(15.58)		
Day	0.89	(1.23)	0.03	(0.04)
Baseline				
Anxiety (HADS-A)	-0.52	(1.68)	0.03	(0.10)
Depression (CES-D)	-0.06	(0.69)	-0.01	(0.12)
Repetitive thought (PTQ)	-0.56	(0.37)	-0.14	(0.09)
Diary				
Nighttime worry (APSQ)	0.91	(0.42)*	0.17	(0.08)*
Daytime worry (APSQ)	-0.64	(0.47)	-0.12	(0.09)
Stress (DASS)	-0.19	(0.84)	-0.02	(0.07)
R^2		3.9%		
		Sleep quality - SQ		
Constant	3.08	(0.24)***		
Day	0.04	(0.02)φ	0.08	(0.05)φ
Baseline				
Anxiety (HADS-A)	-0.02	(0.02)	-0.08	(0.08)
Depression (CES-D)	0.00	(0.01)	0.01	(0.10)
Repetitive thought (PTQ)	0.01	(0.005)*	0.20	(0.08)*
Diary				

(*Continued*)

TABLE 2
(Continued)

	b	(SE)	β	(SE)
Nighttime worry (APSQ)	-0.06	(0.01)***	-0.62	(0.08)***
Daytime worry (APSQ)	0.02	(0.01)**	0.23	(0.09)**
Stress (DASS)	0.01	(0.01)	0.05	(0.07)
R^2		16.6%		

Note. Baseline variables (anxiety, depression, repetitive thought) are the level 2 variables and are measured only once (before filling out the diary). Diary variables (worry and stress) are the level 1 variables and are measured for seven subsequent days. 'Day' is a diary variable (Level 1) and is entered in the model as control variable that indicates which day of the diary was filled out (e.g. Tuesday or Friday). φ = p < .1; * = p < .05; ** = p < .01; *** = p < .001.

O'Kearney & Pech, 2014) and our results suggest that a general tendency to engage in repetitive thinking is not consistently related to sleep impairment. Clearly, more research is needed to clarify for whom, and under what circumstances, worry and rumination are associated with sleep problems.

In study 2, trait repetitive thinking was also found to be unrelated to sleep problems (with the exception of sleep quality) when controlling for depression and anxiety. In this study, we further investigated the effects of daytime and nighttime sleep-related worry on sleep impairment. In line with our expectations, we found that nighttime sleep-related worry was associated with difficulty falling asleep, being awake longer during the night, and sleeping less efficiently. Daytime sleep-related worry was not associated with sleep measures when taking into account the associations between nighttime sleep-related worry and sleep problems. The only exception was that daytime worry was positively associated with sleep quality, while the zero-order correlation between both constructs was in the opposite direction. This could mean that daytime worry improves perceived sleep quality *only* after taking into account effects of nighttime worry. That being said, suppressor effects need to be interpreted with caution if only found on one occasion (Wiggins, 1973), and this finding is in need of replication.

In general, these findings may have some interesting theoretical implications. On the one hand, they disconfirm the part of the cognitive model of Harvey (2002) that suggests that daytime worry is important in explaining sleep disturbance. On the other hand, findings on nighttime worry are in line with the cognitive model (Harvey, 2002) and with previous studies demonstrating an association between sleep impairment and nighttime intrusive thinking (Wicklow & Espie, 2000) and worrying in bed (Weise et al., 2013). In sum, it appears that cognitive activity during the day is relatively benign, but cognitive activity in bed plays an important role in development and persistence of sleep problems in insomnia.

A reason for the importance of nighttime sleep-related worry may be that this process directly influences sleep at night (i.e., a racing mind directly opposes the relaxed state that is needed for sleep). Alternatively, the causal chain may also work in the opposite direction. People who are unable to sleep have time at their disposal and may use this time to start thinking about why they cannot sleep; this in turn may lead to more disrupting sleep-related worry, which starts a vicious circle of wakefulness and worry. Since we have no information about the direction of this association, future studies should aim to clarify the nature of this relationship.

This study had a number of methodological limitations. First, the timing of measurements was a challenge. For instance, in both studies, the daytime worry and stress diary was sent by e-mail at 7:00 p.m.. As a result, participants may not have reported on their thoughts in the late evening, which may be a time when daytime worry could have a stronger influence on sleep. In a similar vein, nighttime worry was assessed the next morning, which introduces the possibility of recall bias into these measurements. To limit biased reporting of repetitive thinking, we recommend using data collection methods that maximize ecological validity, such as Ecological Momentary Assessment (EMA; Shiffman, Stone, & Hufford, 2008) in future research. Second, our ability to chart all effects of diurnal variations of different types of repetitive thinking was limited in both studies. In study 1, we decided to remove the diary measures of repetitive thinking because these appeared contaminated. In study 2, we measured (daytime and nighttime) sleep-related worry but not sleep-related rumination. Future research should therefore aim to extend our findings, for instance by adding a daytime and nighttime measure of the new Daytime Insomnia Symptom Response Scale, a measure for sleep-related rumination (Carney et al., 2013). A third limitation is that we exclusively relied on subjective measures to assess sleep. For future investigations, we recommend combining subjective (e.g., questionnaires, diaries) and objective measures (e.g., actigraphy, polysomnography; cf. Spiegelhalder et al., 2012) to obtain a more fine-grained view of the effects of repetitive thinking on sleep problems.

Furthermore, there were some limitations due to sampling. First, participants were self-selected and this may have led to a sample of people with a disproportionate interest for repetitive thinking. This potentially reduces the external validity of the studies. It may also have reduced the internal validity, since this self-selection may have restricted the range of the scores on variables and as a consequence the strength of the observed relationships. Second, in study 2, the sample size was relatively small (n = 64), which may indicate potential power problems. However, since the relationships between nighttime sleep-related worry and sleep problems were strong and effects of daytime sleep-related worry were (very) small, it is improbable that recruiting a larger sample would alter our conclusions. Lastly, there was some missing data in the sleep-related worry diary of study 2 (12%). Nevertheless, we are confident that the small proportion of missing data did not bias our estimations, because multilevel regression analyses can handle missing data very well (Hox, 2002).

Notwithstanding these limitations, the findings observed in this study are important and warrant further investigation. To our knowledge, this was the first time that the effects of trait worry and rumination and daytime and nighttime sleep-related worry have been compared within one investigation. This comparison has led us to conclude that nighttime sleep-related worry (but not trait repetitive thinking and daytime sleep-related worry) is an important factor in the development and persistence of sleep problems in insomnia. Although future research aimed at replicating these findings using more advanced and objective techniques is needed, these results have potential implications for treatment. In CBT for insomnia, several techniques to reduce repetitive thinking are routinely employed (for reviews: Morin & Espie, 2003; Perlis, Aloia, & Kuhn, 2011). Our findings suggest that therapists may need to focus more on targeting nighttime sleep-related repetitive thinking to further improve the efficacy of CBT for insomnia.

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SUPPLEMENTAL DATA

Supplemental data for this article can be accessed on the publisher's website.

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